OTHER

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DEPARTMENT OF MECHANICAL ENGINEERING

Thesis Abstracts

MULTI-LEVEL TECHNIQUE FOR STIFFNESS AND STRENGTH CALCULATIONS OF WOVEN FABRIC COMPOSITE PLATE AND SHELL STRUCTURES

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The stiffness and strength behavior of the woven fabric composite materials mainly depend on the properties of the fiber and matrix materials. A technique was developed to design and analyze woven fabric composites based on the micro-level properties of the fiber and matrix materials. The technique is based on the bilateral relationships among the fiber/matrix materials, the unidirectional composite (strand), the woven fabric layer and the laminated composite structure as in the given order. Simplified and efficient analytical models were developed for the relationship between any subsequent levels. The technique is used to predict the structural level stiffness and strength in terms of material and geometric configuration of the woven fabric and lamination. Progressive damage/failure can also be simulated at the fiber and matrix level by using this technique.

DoD KEY TECHNOLOGY AREA: Materials, Process and Structures

KEYWORDS: Multilevel Technique, Woven Fabric Composite, Fiber, Matrix, Strand, Plate, Shell, Volume Fraction, Damage Size, Undulation Angle, Failure Criteria

ADAPTIVE MULTI-LAYER LMS CONTROLLER DESIGN AND ITS APPLICATION TO ACTIVE VIBRATION SUPPRESSION ON A SPACE TRUSS

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This thesis develops an adaptive controller that actively suppresses a single frequency disturbance source at a remote position and tests the system on the NPS Space Truss. The experimental results are then compared to those predicted by an ANSYS finite element model. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment mounted at its extremities. One of two installed piezoelectric actuators and an Adaptive Multi-Layer LMS control law were used to effectively eliminate an axial component of the vibrations induced by a linear proof mass actuator mounted at one end of the truss. Experimental and analytical results both demonstrate reductions to the level of system noise. Vibration reductions in excess of 50dB were obtained through experimentation and over 100dB using ANSYS, demonstrating the ability to model this system with a finite element model. This thesis also proposes a method to use distributed quartz accelerometers to evaluate the location, direction, and energy of impacts on the NPS space truss using the dSPACE data acquisition and processing system to capture the structural response and compare it to known reference signals.

DoD KEY TECHNOLOGY AREA: Space Vehicles, Modeling and Simulation

KEYWORDS: Active Vibration Suppression, Piezoceramic Actuators, Impact Analysis, Adaptive Controller, LMS

COMPUTATIONAL MECHANICS OF THE FULL-SCALE AND MODEL-SCALE ROLL-ON, ROLL-OFF (RORO) STERN RAMP AND EXPERIMENTAL MODAL ANALYSIS OF THE MODEL-SCALE RAMP AND SUPPORT

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It has been determined that current stern ramp designs lack adequate structural integrity during Sea State Three roll-on, roll-off (RORO) operations. Therefore, passive isolation between the stern ramp and the RORO discharge facility (RRDF) is being investigated as a means of reducing ramp stress levels. A coupled hydro-structural simulation model of the combined ship-ramp-RRDF is under development in order to evaluate candidate isolator technologies. This thesis documents a thorough study of several stern ramp finite element models in order to ascertain the suitability of these models for use in the simulation model. Additionally, an experimental facility is being developed to simulate, at model scale, RORO operations. This thesis also documents the finite element analysis and experimental modal analysis of the primary structural components of the facility, specifically the scale model stern ramp and its support.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Roll-On, Roll-Off, RORO, Stern Ramp, Isolation

SINKING A BODY WITH BUBBLES IN CLOSED AND OPEN ENVIRONMENTS

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Second Reader: Ashok Gopinath, Department of Mechanical Engineering

The presence of bubbles in a liquid decreases the average density, and thus decreases the buoyant force on a floating body. Competing with the decrease in buoyancy is an upward drag due to the bubble motion and entrained liquid. This thesis presents investigations of the critical average density required to sink a buoyant body in water with bubbles in closed and open environments. A closed environment is where bubbles fill the container, in which case there is expected to be little if any upward flow of water at the body. An open environment is where the bubbles exist over a small cross-sectional area compared to the total cross-sectional area of the container, which models the effect of a methane eruption from the ocean floor. In this case, a substantial upward flow of water is entrained in the region of the bubbles, and a downward flow consequently occurs outside this region. Experiments for both closed and open environments are reported, where the average specific gravity of the body is varied. The closed environment data significantly deviate from a quantitative theory, and the open environment data are not in accord with a qualitative theory. Possible explanations for these deviations are offered.

DoD KEY TECHNOLOGY AREA: Other (Fluid Dynamics)

KEYWORDS: Water, Density, Specific Gravity, Volume Fraction, Bubbles, Buoyancy, Nonnewtonian Fluid

MODELING THE EFFECT OF CYCLING OF A LOCALIZED HEAT SOURCE IN THE DIE OF A FLIP CHIP PACKAGE WITH DEFECTS

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Advisor: Ashok Gopinath, Department of Mechanical Engineering

In this study, the finite element based numerical tool ANSYS was used to perform a nonlinear transient coupled-field thermal and structural analysis on a flip chip package. The effect of cycling of a localized source of heat, the die was studied in order to determine the possible formation of hot spots in a flip chip package with conduction inhibiting defects such as imperfect contact between the bump and pad. Different heat source levels and defect severities (characterized by reduced bump pad conductivities) were analyzed by subjecting the package to two step-change thermal cycles for each case studied. The thermal results indicate significant temperature differences within the package in all cases thus pointing to the need for a non-isothermal analysis. The structural results indicate a seemingly anomalous behavior of increased cycles to failure with increasing power and severity of defect which can be explained by the rapidly varying nature of the stresses thus resulting in minimal creep damage.

DoD KEY TECHNOLOGY AREAS: Other (Electronic Packaging)

KEYWORDS: Flip Chip, Electronic Packaging, Thermomechanical Fatigue

MODELING OF SHIPBOARD SMOKE PROPAGATION WITH A FORCED COUNTER-FLOW AIR SUPPLY

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The propagation of fire-generated smoke with a counter-flow air supply in a horizontal arrangement of shipboard compartments and passageways was modeled using a computational fluid dynamics program generated by Computational Fluid Dynamics Research Corporation. This study was based on a large-scale live fire experiment performed by Naval Research Laboratory on the ex-USS SHADWELL. All simulations were evaluated at steady state conditions. A constant velocity counter-flow air supply was introduced into the model structure. The counter-flow air velocities used were 0.5, 1, and 2 m/s. This study used a Computational Fluid Dynamics combustion module to simulate a 620 kW fire generated by the complete combustion of propene gas from a burn pan in the space. Carbon dioxide from the fire was tracked throughout the structure to model smoke propagation. Seven simulations were performed with adiabatic and isothermal bulkhead, deck and overhead boundary conditions. Simulation smoke propagation results were consistent with experimental observations. Figures depicting temperature distribution, carbon dioxide distribution and mixture flow patterns at specified locations are provided in the report. The goal of this study is to evaluate the effectiveness of computational fluid dynamics modeling of smoke propagation in a shipboard space with a counter-flow air supply.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Smoke, Smoke Modeling, Smoke Propagation, Smoke Spread, Smoke Movement, Computational Fluid Dynamics, Control Shipboard Smoke, Fire Induced Flow, Fire Spread, Field Modeling, Damage Control, Convection, Forced Air Supply

MODELING THE BIODYNAMICAL RESPONSE OF THE HUMAN HEAD FOR INJURY ANALYSIS

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The objective of this study is to develop a finite element model of the human head and neck to investigate the biomechanics of head injury. The finite element model is a two-dimensional, plane strain representation of the cervical spine, skull, and major components of the brain including the cerebrum, cerebellum, brain stem, tentorium and the surrounding cerebral spinal fluid. The dynamic response of the model is validated by comparison with the results of human volunteer sled acceleration experiments conducted by Ewing et al. To validate the head model, one of the head impact experiments performed on cadavers by Nahum et al. is simulated. The model responses are compared with the measured cadaveric test data in terms of head acceleration, and intracranial pressures measured at four locations including the coup and contrecoup sites. The validated model is used to demonstrate that the Head Injury Criterion (HIC), which is based on resultant translational acceleration of the center of gravity of the head, does not relate to the various mechanisms of brain injury and is therefore insufficient in predicting brain injury.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Finite Element Method, Human Thorax Model, Biodynamical Response

DETERMINATION OF INCLUSION CHEMISTRY AND SIZE DISTRIBUTION IN STEEL WELDMENTS BY ANALYTICAL ELECTRON MICROSCOPY

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The U. S. Navy has been concerned about reducing the number of inclusions in steel weldments to increase the toughness of the weld metal. Research has shown that particular inclusions can nucleate the acicular ferrite microstructure in the weld metal, which can increase toughness without compromising strength. The present study investigated the inclusion chemistry and size distribution in aluminum-deoxidized C-Mn steel weldments. The results showed that the addition of aluminum to the C-Mn weld metal will produce inclusions, that can nucleate acicular ferrite by epitaxy, and that the number and volume fraction of inclusions is reduced. This indicates that aluminum deoxidation of steel weld metal can have positive benefits for C-Mn weld metal strength and toughness.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Acicular Ferrite, Shielded Metal Arc Welding, C-Mn Steel Weldments, Non-metallic Inclusions

RECURSIVE BLOCK-BY-BLOCK INTEGRAL EQUATION SOLUTION FOR TRANSIENT DYNAMIC ANALYSIS WITH MEMORY-TYPE ELEMENTS

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An efficient method of computing structural response of multi-story nonlinear base isolated buildings for a given seismic event is presented. Using a recursive block-by-block integral equation formulation (RBBIEF) solution to the governing nonlinear Volterra integral equation, structural base motion coupled to an

arbitrary number of nonlinear base isolators can be computed for discrete seismic time histories in an expeditious and exacting manner. The general solution to the governing nonlinear Volterra integral is formulated and subsequently converted into code using MATLAB. The succeeding analysis incorporates modal properties, computed from conventional finite element (FE) techniques, and the generated MATLAB programs to solve a varying set of multi-degree of freedom structures coupled to both linear and nonlinear isolators. Ultimately, an analysis is conducted on a 30-story building that was overly designed using the 1994 Load Resistance Factor Design and the 1994 Uniform Building Codes for earthquake loading. The method demonstrates that the Volterra integration scheme in the time domain is very effective and efficient.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Materials, Processes, and Structures, Modeling and Simulation, Other (Civil Engineering)

KEYWORDS: Finite Element, Nonlinear Dynamic Transient Response, Seismic Response, Volterra integral, Convolution Integral, Nonlinear Structural Base Isolation, Hysteretic isolators

AUV STEERING PARAMETER IDENTIFICATION FOR IMPROVED CONTROL DESIGN

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Master of Science in Mechanical Engineering-June 2001
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Any effort to provide precision control for an Autonomous Underwater Vehicle requires an accurate estimation of both the vehicle's physical and hydrodynamic parameters. Here a vehicle model for controlled steering behaviors was developed and the hydrodynamic parameters were calculated from actual data obtained from operation. The steering equation parameters are based on a least squares fit to sideslip and turn rate data using maximum likelihood of batch processing. In this way, a more accurate simulation has been found for the development of a track controller that stably drives the vehicle between mission waypoints. Prediction accuracy of the model was better than ninety-five percent over the data set used.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Aircraft

KEYWORDS: Underwater Vehicle, AUV, Control, System Identification, Autonomous Systems, Robotics

SEMI-RIGID TOWING MODEL FOR ANALYSIS OF MANUEVERING IN THE HORIZONTAL PLANE

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A SIMULINK towing model is developed from the surge, sway, and yaw equations of motion in order to study the horizontal maneuverability of vessels in a semi-rigid towing operation. This analysis is conducted in order to validate rigid-connection towing and to give insight into the design of the tow connector. The connection is modeled as a linear spring and the maneuverability of the vessels is studied as the stiffness is varied from conditions of semi to completely rigid. This study is based on two Swath hull vessels, the SLICE and KAIMALINO, towing in close proximity under calm water conditions.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Towing, SeaKeeping

COUPLED LAGRANGIAN AND EULERIAN APPROACH TO DETONATION AND FRAGMENTATION PROBLEMS

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Many obstacles such as minefields, barbwire entanglements, tank ditches and other fortifications are used to paralyze the forward momentum of mechanized armed forces. To combat this the Grizzly tracked vehicle was developed for the United States Army. Due to the Grizzly's mission various sensors; laser systems, hydraulic lines, wires and cameras are mounted on the armor hull, which are exposed to various types of landmine detonation and fragmentation. This thesis studies the effects of shock waves and fragmentation on the survivability of the equipment mounted on the Grizzly's armored hull. Models of an OZM-72 antipersonnel mine are developed and used to simulate the detonation and fragmentation phenomena. The analysis results obtained from the models provide a basis from which design guidance can be formulated for protecting equipment or personnel from this threat.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Fragmentation, Detonation, Land Mine

STRUCTURAL HEALTH MONITORING: NUMERICAL DAMAGE PREDICTOR FOR COMPOSITE STRUCTURES

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The use of composite materials in both civil and military applications is increasing as composites potentially offer many advantages over traditional structural materials. Composites typically provide superior strength to weight ratio, better resistance to corrosion, and especially for military applications, greater ballistic protection. Wide use of composites is found in aircraft, armored vehicles, ships and civil structures.

This present research demonstrates the ability to numerically detect damage in a composite sandwich structure using a robust non-linear finite element model (FEM). FEM techniques are used to directly represent damage and the model's response is investigated. Changes in elemental strain and strain frequency, through a Fast Fourier Transform (FFT), is evaluated. Both a cantilevered beam and a simply supported plate are studied.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Manufacturing Science and Technology (MS&T), Modeling and Simulation, Other (Civil Engineering)

KEYWORDS: Structural Health Monitoring, Finite Element Method, Composites, DYNA3D, and Non-Destructive Damage Detection

MODELING THE BIODYNAMICAL RESPONSE OF THE HUMAN THORAX WITH BODY ARMOR FROM A BULLET IMPACT

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Master of Science in Mechanical Engineering-March 2001
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The objective of this study is to develop a finite element model of the human thorax with a protective body armor system so that the model can adequately determine the thorax's biodynamical response from a

projectile impact. The finite element model of the human thorax consists of the thoracic skeleton, heart, lungs, major arteries, major veins, trachea, and bronchi. The finite element model of the human thorax is validated by comparing the model's results to experimental data obtained from cadavers wearing a protective body armor system undergoing a projectile impact. When the model is deemed valid, a parametric study is performed to determine the components of the model that have the greatest effect on its biodynamical response to a projectile impact.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Conventional Weapons

KEYWORDS: Finite Element Analysis, Human Thorax Model, Impact Analysis, Body Armor

EVALUATION OF THE USE OF GPS-AIDED WEAPONS TO ATTACK MOVING TARGETS
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The current intelligence gathering and strike decision infrastructure is optimized to handle geographically and temporally fixed targets. When tasked to respond to targets that require near immediate engagement, however, the system is stressed to the limit of its capability. When these time sensitive targets are capable of relocating, the process of rapidly applying lethal force becomes even more complicated. This thesis examines the problems associated with attacking a moving target using low cost GPS-aided standoff weapons, without an integrated weapon seeker. It begins with a discussion of the history and evolution of the Navy's ability to attack time sensitive moving targets, and provides the description of a system that could address shortcomings noted. MATLAB(Simulink(was used to develop a model to simulate the proposed system, and determine the responses to various combinations of identified error sources. The results of the research showed that the type of system proposed is technically feasible.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control, and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Other (Time Critical Strike)

KEYWORDS: GPS, Weapon, Modeling, CEP, Time Sensitive Targets, Command Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Time Critical Strike, Stand-off Weapons

SURFACE SHIP SHOCK MODELING AND SIMULATION: EXTENDED INVESTIGATION
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Mechanical Engineer-December 2000
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Surface Ship Shock trials play an essential role in ship test and evaluation (T&E), and Live Fire Test and Evaluation (LFT&E) requirements for the lead ship of each new construction shock hardened ship class. These tests provide insight into platform vulnerabilities with respect to close proximity underwater explosion (UNDEX) events, and produce significant decision-making data for corrective action. The high cost of conducting ship shock trials has lead to a significant effort to develop modeling and simulation capabilities that can provide decision-making data comparable to that gained from the actual tests. Unfortunately, efforts to capture the response of a ship's structure to an UNDEX event require extremely large and complex finite element models of not only the ship's structure but the surrounding fluid. This fluid volume is required to capture the effects of the cavitation caused by the UNDEX shock waves. The computational expense of running these finite element models is tremendous. This thesis reviews the work on this subject completed at the Naval Postgraduate School. Additionally, it provides further investigation

into the amount of the fluid that must be modeled to accurately capture the structural response of a 3D finite element model and presents a second generation finite element model of the USS JOHN PAUL JONES (DDG 53) for use in 3D analysis.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Computing and Software, Conventional Weapons, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Underwater Explosion, Shock and Vibration

AN EXPERIMENTAL INVESTIGATION OF THE BOW WAVE ON *USS COLE* (DDG-67)
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This is an experimental investigation into the formation of the bow wave on *USS COLE* (DDG-67) and her 1/250 scale model. The experiment examines the bow wave from a hydrodynamic signature point of view. Previous experiments have looked at the phenomenon from an icing, deck wetness or hull resistance standpoint. Very little research has emphasized the importance to the Navy of the effects of the bow wave and subsequent spray on the overall radar cross-section and stealth of the vessel. Measurements were conducted on a 1/250-scale model and compared to video of the *USS COLE* (DDG-67) wherever possible. The effects of steady, heave, pitch and combinations of heave and pitch motions were studied to quantify the base flow in comparison to the *USS COLE*. The Froude Number for the majority of the work was 0.25. Model scale frequencies ranged from 1 to 5 Hz, pitch angles from 0.85 degrees to 3.75 degrees and heave amplitudes from 1/8 to 1/2 of an inch. This research, coupled with subsequent studies of sheet separation and a physics based understanding of all the mechanisms, is essential to developing a numerical model that could begin to predict the basics of the highly complex bow wave and spray region.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Hydrodynamics, Bow Wave, *USS Cole*

VALIDATION OF LOW OBSERVABLE STACK EDUCTOR DESIGN FOR GAS TURBINE EXHAUST SYSTEMS
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Mechanical Engineer-September 2001
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An experimental and analytical program was conducted to improve the entrainment performance of a low aspect ratio mixing tube (about unity) eductor. A new primary flow pattern, consisting of eight high aspect ratio, pie-shaped nozzles, was designed to increase mixing and product better outlet flow uniformity. The aerodynamic performance of the new design was measured in a 1/5 scale, cold-flow facility, and the results compared to a nozzle plate with 16 constant-width, radial nozzles. Experimental results are presented for a range of conditions and include the effects of mixing tube misalignment and inlet blockage. The new nozzle is shown to increase the secondary pumping ratio by 7%. In addition, a one-dimensional, steady, analytical model of an educator, which includes frictional losses and outlet momentum non-uniformity is presented. The model predicts the performance of real eductors to within 3% and shows that the momentum non-uniformity is the primary factor limiting performance.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Signature Control, Gas Turbines, Propulsion

DEVELOPMENT OF A MODEL TO PREDICT AND ASSESS SURFACE SHIP RECOVERABILITY

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Survivability has become an increasingly important issue in the design of future naval warships. Quantifiable requirements for susceptibility and vulnerability have long been employed, but no model or computational methods exist to calculate the ability of a surface ship to "control the spread of damage and restore lost capabilities." Recoverability is defined as the probability of recovering from damage caused by a specific weapon. This thesis analyzes the complex issues involved in determining recoverability and setting parameters for recoverability measurement criteria. Two methods to calculate the probability of recovery, PR, are proposed along with sample data, analysis and applications. The variables and information required to implement the methodologies are outlined in significant detail to provide a basis for future model development.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Ship Survivability, Survivability, Damage Control, Recoverability, Ship Design

VERTICAL PLANE RESPONSE OF SURFACE SHIPS IN CLOSE PROXIMITY TOWING

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The purpose of this thesis is to analyze the vertical plane response of surface ships in close proximity towing. The problem is formulated by using the heave and pitch equations of motion in regular waves. The vertical motion of the leading and trailing ship attachment points is calculated. The relative motion between these points is then matched through a notional spring/damper model of the connection. This allows calculation of the complete response amplitude operators for the two ships in terms of their relative motion and connection force. Parametric studies are conducted in terms of connection spring and damper characteristics, speed, and sea direction. Regular wave results are extended in standard fully developed random seas. A notional example provides insight into future studies necessary to validate the close-proximity towing concept.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Slice, Kaimalino, Seakeeping, Swath, RAO

A HOT-STAGE ATOMIC FORCE MICROSCOPE FOR THE MEASUREMENT OF PLASTIC DEFORMATION IN METALLIC THIN FILMS DURING THERMAL CYCLING

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An Atomic Force Microscope is equipped with a hot-stage and a vacuum system in order to enable in-situ studies of plastic deformation and interfacial sliding of thin metallic films on Si substrates during thermal cycling. The apparatus can reach sample temperatures of 100(C while maintaining optimum resolution. The system will allow future in-situ thermal cycling experiments on microelectronic devices in a protected environment to provide insight into the role of plastic deformation in metallic thin films on the stability of future generations of device structures. The details of the design, along with the performance limitations of the system are discussed. Preliminary results demonstrating the performance of the system at an elevated temperature are presented. Limited post-situ results from direct measurement of the plastic deformation of thin Cu films on Si substrates induced by thermal cycling are also presented, primarily with the objective of establishing the need for detailed in-situ studies. While artifacts such as permanent dimensional changes of the film are observed post-situ, a detailed mechanistic understanding of the interaction between the temperature-dependent stress state of the film and the resultant inelastic deformation within the film and at the interface can only be obtained through in-situ experiments.

DoD KEY TECHNOLOGY AREA: Electronics, Materials, Processes, and Structures

KEYWORDS: Atomic Force Microscopy, Creep Mechanisms, Hot-Stage, Interfacial Sliding, Microelectronic Devices, Thin Films, Vaccum System

A FINITE ELEMENT ANALYSIS OF THERMAL FATIGUE STRESSES IN THE SOLDER JOINTS OF A FLIP CHIP PACKAGE

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A nonlinear finite element model was created using ANSYS to analyze the deformation and stresses in the solder bumps of a flip chip package subjected to thermal cycling. A parametric study of the effects of different dwell times, temperature ranges, and ramp rates in a thermal fatigue cycle was conducted for two different package geometries. The goal of this study was to use an energy density damage analysis to investigate the reliability (in cycles to failure) of a typical flip chip package by examining critical solder bump stress-strain behavior due to thermal cycling. The creep damage mechanism was found to be the primary mode of failure, which severely limited package life. A concurrent study of the behavior of the package with and without underfill showed that the bumps surrounded by under fill experienced considerably lower creep damage due to increased hydrostatic stresses, which in turn significantly extended the life of the package.

DoD KEY TECHNOLOGY AREAS: Other (Electronic Packaging)

KEYWORDS: Flip Chip, Electronic Packaging, Thermomechanical Fatigue

PRODUCTION OF ULTRA-FINE GRAINS AND EVOLUTION OF GRAIN BOUNDARIES DURING SEVERE PLASTIC DEFORMATION OF ALUMINUM AND ITS ALLOYS

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Equal channel-angular pressing (ECAP) is a recently developed method for deformation processing of material that can produce an ultra-fine grain structure in bulk material through severe plastic deformation. This study will present results on microstructural evolution during repetitive ECAP of pure aluminum. The principal method of data collection was Orientation Imaging Microscopy (OIM). The results of the study indicate that, after one ECAP pass, the structure is inhomogeneous and anisotropic, and consists mostly of deformation-induced features. After repetitive ECAP, the aluminum material exhibited a homogeneous grain size but retained an anisotropic character to the microstructure. After twelve ECAP passes the microstructure consisted mainly of fine grains surrounded by high-angle boundaries but an appreciable fraction of low-angle boundaries remained. This microstructure thus comprises a mixture of deformation-induced and recrystallization features. Further results were also obtained documenting the existence of deformation banding in this material as well as in a rolled aluminum alloy. This phenomenon may be general in nature and associated with severe plastic deformation in aluminum and its alloys.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Manufacturing Science and Technology (MS&T)

KEYWORDS: Equal Channel-Angular Pressing, Ultra-fine Grains, Grain Refinement, Plastic Deformation, Deformation Banding, Misorientation Angle, Orientation Imaging Microscopy, Electron Backscatter Diffraction, Supral 2004, Nano Structures, Severe Plastic Deformation

DEVELOPMENT OF EXPERIMENTAL FACILITY FOR ROLL-ON ROLL-OFF RAMP ISOLATION DYNAMICS

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Fotis A. Papoulias, Department of Mechanical Engineering

It has been determined that a high stress state occurs in the Roll-on Roll-off (RORO) ship offload stern ramp during vehicle transfers in Sea State 3 conditions. Motion compensation systems (i.e. isolators) between the ramp and the barge (RRDF) are needed to minimize the high stress levels in the ramp. This thesis documents the design, analysis, and construction of a facility to evaluate the performance of candidate isolation systems to be used to minimize ramp stresses. The facility consists of a fabricated aluminum scale ramp model designed to mimic the structural dynamics of a full-scale ramp, a fabricated supporting structure and an actuator that simulates wave motion inputs to the barge-end of the isolator.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Isolation, Roll-on, Roll-off, RORO, Stern Ramp

FLOW CHARACTERISTICS OF LIQUID EPOXY UNDERFILL IN A NARROW GAP FOR FLIP CHIP DEVICES

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The flow characteristics of a liquid epoxy encapsulant designed as an underfill for flip chip computer devices was studied in a controlled manner. Different temperatures, patterns, underfills, and points of application were used to investigate the characteristics of capillary flow through a narrow gap to determine optimal conditions of importance in computer flip chip manufacturing. Observations on flow front uniformity, void formations, distance/time covered, were recorded for all experimental runs. Qualitative visual data was recorded to corroborate the trends found for liquid underfill flow in a flip chip device. This data has been used to generate time-distance plots for determining optimal conditions for flow. The results of this work provide useful fundamental insight into fluid mechanics issues of flip chip computer device manufacturing posed by the challenges of continually decreasing computer chip size.

DoD KEY TECHNOLOGY AREA: Manufacturing Science and Technology (MS&T)

KEYWORDS: Flip Chip, Capillary Flow, Liquid Epoxy Underfill